NESCAUM staff analysis of PM$_{2.5}$ NAAQS

Presentation to the
Massachusetts SIP Steering Committee Meeting.
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Northeast States for Coordinated Air Use Management (NESCAUM)

Overview

- **Health factors**
  - Health effects associated with $PM_{2.5}$ exposure
  - Northeast susceptible populations
  - Threshold concerns
  - EPA currently revising $PM_{2.5}$ primary (health-based) standards.

- **NESCAUM staff analysis of primary $PM_{2.5}$ standards**
  - Relationship between annual and daily levels.
  - Effect of alternative $PM_{2.5}$ standards on populations

Public health factors relating to selection of PM$_{2.5}$ standards

1. Health effects: Epidemiologic studies have shown statistically significant associations between short- and long-term ambient fine PM exposures with a variety of human cardiac and respiratory health endpoints. New epidemiologic studies have extended earlier results to more cities. See Tables 1 and 2. Findings enhanced by toxicologic and dosimetric research supporting theories of mechanism. Short-term exposures (<24 hours) of growing concern.

> *But which constituent of PM? What source(s) are responsible? Hypotheses include ultrafine particles, mobile sources, metals, etc.*

2. Susceptible populations [% in 8-state region]: Subgroups at higher risk to PM$_{2.5}$ include children [25%]; adults with diabetes, heart disease, or lung disease [4-18%]; older persons [13%]; persons at heightened exposure scenarios (e.g., outdoor activity, proximity to intense sources). Northeast U.S. densely populated and urban [72%]. See Table 3 and Figure 1.

> *Additional subgroups? Prenatal exposures, socio-economic status (SES)?*

3. Threshold concerns and adequacy of the current PM$_{2.5}$ standards: Fine particle exposure-response relationships appear to be linear without clear evidence of a threshold, suggesting that health effects may be observed at lower concentrations as well as higher ones. These include findings of effects at levels below the level of the EPA current 24-hour average and annual PM$_{2.5}$ standards. The Clean Air Act mandates EPA consider sensitive subpopulations in setting standards to protect the public's health with an adequate margin of safety (to prevent an unacceptable risk of harm). See Table 4.

How to select protective standards in accordance with Clean Air Act mandate to protect susceptible groups if no "bright line" exists?

Table 1: **Statistics for 24-hour PM$_{2.5}$ concentrations from U.S. and Canadian health studies (up to means of 18 µg/m^3) (EPA 2003, 2004).**

Study Location	Mean	98th %	Health endpoint	% increase (95%CI) per 25 µg/m^3 PM$_{2.5}$
Stieb et al. 2000, St. John CAN	8.5	27.3	Total Cardiovas Hosp Admis	GAM not used 15.11 (0.25, 32.8)
			Total Resp Hosp Admis	GAM not used 5.69 (0.61, 11.03)
Schwartz 2003, Portage WI	11.2	34.3	Total Mortality	GLM BS 1.5 (-2.7, 5.8)
				GLM PS 1.1 (-3.1, 5.4)
Schwartz 2003, Topeka KS	12.2	32	Total Mortality	GLM BS 1.3 (-6.2, 9.3)
				GLM PS 1.4 (-6.3, 9.6)
Burnett and Goldberg, 2003, 8 Canadian Cities	9.5-17.7	38.9	Total Mortality	GAM Strict 2.8 (1.2, 4.4)
				GLM NS 2.1 (0.1, 4.2)
Mar et al. 2003, Phoenix AZ	13.5	32.2	Total Cardiovas Mortality	GAM Strict 18.0 (4.9, 32.6)
				GLM NS 19.1 (3.9, 36.4)
Fairley, 2003, Santa Clara County CA	13.6	59	Total Mortality	GAM Strict 8.1 (1.6, 15.0)
				GLM NS 7.0 (1.4, 13.0)
			Total Resp Mortality	GAM Strict 11.7 (-9.8, 38.3)
				GLM NS 13.5 (-3.6, 33.7)
Delfino et al. 1997, Montreal CAN	14.7	50.2	Total Resp Hosp Admis	GAM not used 23.88 (4.94, 42.83)
Schwartz 2003, Boston MA	15.7	42	Total Mortality	GLM BS 5.0 (3.1, 7.0)
				GLM PS 4.5 (2.5, 6.5)
Ostro et al. 2003, Coachella Valley CA	15.8	33.8	Total Cardiovas Mortality	GAM Strict 9.8 (-5.7, 27.9)
				GLM NS 10.2 (-5.3, 28.3)
Thurston et al. 1994, Toronto CAN	15.8-22.3	51	Total Resp Hosp Admis	GAM not used 15.00 (1.97, 28.03)

Table 1, cont: **Statistics for 24-hour PM$_{2.5}$ concentrations from U.S. and Canadian health studies (up to means of 18 μg/m^3) (EPA 2003, 2004).**

Study Location	Mean	98th %	Health endpoint	% increase (95%CI) per 25 μg/m^3 PM$_{2.5}$
Sheppard et al. 2003, Seattle WA	16.7	46.6	Asthma Hosp Admis	GAM Strict 8.7 (3.2, 14.4) GLM NS 6.5 (1.1, 12.0)
Burnett et al. 1997, Toronto CAN	16.8	47.4	Total Cardiovas Hosp Admis Total Resp Hosp Admis	GAM not used 7.18 (-0.61, 15.6) GAM not used 8.61 (3.39, 14.08)
Lipfert et al. 2000, Philadelphia PA	17.3	44.2	Total Mortality Total Cardiovas Mortality	GAM not used 4.21 (p<0.055) GAM not used 5.0 (2.4, 7.5)
Goldberg and Burnett 2003, Montreal CAN	17.4	53.1	Total Mortality	GAM Strict 4.2 (p<0.05) GLM NS 1.5 (p>0.05)
Ito 2003, Detroit MI	18	55.2	Total Mortality	GAM Strict 1.9 (-1.8, 5.7) GLM NS 2.0 (-1.7, 5.8)
			Total Cardiovas Mortality	GAM Strict 2.2 (-3.2, 7.9) GLM NS 2.0 (-3.4, 7.7)
			Total Resp Mortality	GAM Strict 2.3 (-10.4, 16.7) GLM NS 3.1 (-9.7, 17.7)
			Ischemic Heart Disease Hosp Admis	GAM Strict 3.65 (-2.05, 9.7) GLM NS 3.0 (-2.7, 9.0)
			Dysrhythmias Hosp Admis Heart Failure/Cong Heart Disease Hosp Admis	GAM Strict 3.2 (-6.6, 14.0) GLM NS 2.6 (-7.1, 13.3) GAM Strict 8.0 (1.4-15.0) GLM NS 6.8 (0.3-13.8)
			Stroke Hosp Adms	GAM Strict 1.94 (-5.16, 9.57) GLM NS 0.97 (-6.06, 8.52)
			Pneumonia Hosp Admis	GAM Strict 10.5 (1.8, 19.8) GLM NS 10.1 (1.5, 19.5)
			COPD Hosp Admis	GAM Strict 3.0 (-6.9, 13.9) GLM NS 0.3 (-9.3, 10.9)

Table 2: **Statistics for $PM_{2.5}$ concentrations from cohort long-term health studies (EPA 2003, 2004).**

Study	Mean	Range	Health endpoint	% increase (95%CI) per 10 µg/m^3 $PM_{2.5}$
Harvard Six-Cities, Dockery et al. 1993	NR	11-30	Total Mortality	1.13 (1.04, 1.23)[1]
			Cardiopulmonary Mortality	1.18 (1.06, 1.32)[1]
			Lung Cancer Mortality	1.18 (0.89, 1.57)[1]
American Cancer Society (ACS), Pope et al. 1995	20	9-34	Total Mortality	1.07 (1.04, 1.10)
			Cardiopulmonary Mortality	1.12 (1.07, 1.17)
			Lung Cancer Mortality	1.01 (0.91, 1.12)
ACS extended reanalysis, Pope et al. 2002	14	6-21	Total Mortality	1.06 (1.02, 1.11)
			Cardiopulmonary Mortality	1.08 (1.02, 1.14)
			Lung Cancer Mortality	1.13 (1.04, 1.22)

[1]Values fitted to 10 µg/m^3 increment by EPA

Table 3: **Population density and total population of selected states (2000 U.S. Census).**

State	Population density per mile^2 land area	Population density rank	Total population	Total population rank	Land area (mile^2)	Land area rank
NJ	1,134	1	8,414,350	9	7,419	47
RI	1,003	2	1,048,319	43	1,045	50
MA	810	3	6,349,097	13	7,838	44
CT	703	4	3,405,565	29	4,845	48
MD	542	5	5,296,486	19	9,775	42
NY	402	6	18,976,457	3	47,224	27
DE	401	7	783,600	45	1,955	49
FL	296	8	15,982,378	4	53,997	22
OH	277	9	11,353,140	7	40,953	34
PA	274	10	12,281,054	6	44,819	33
NH	138	20	1,235,786	41	8,969	46
VT	66	30	608,827	49	9,249	45
ME	41	38	1,274,923	40	30,865	39
NESCAUM	352		41,313,324		117,454	
U.S.	80		281,421,906		3,794,083	

Figure 1: **Population density by census tract. >200 persons/mile^2 (yellow); >1,000 persons/mile^2 (red) (2000 U.S. Census).**
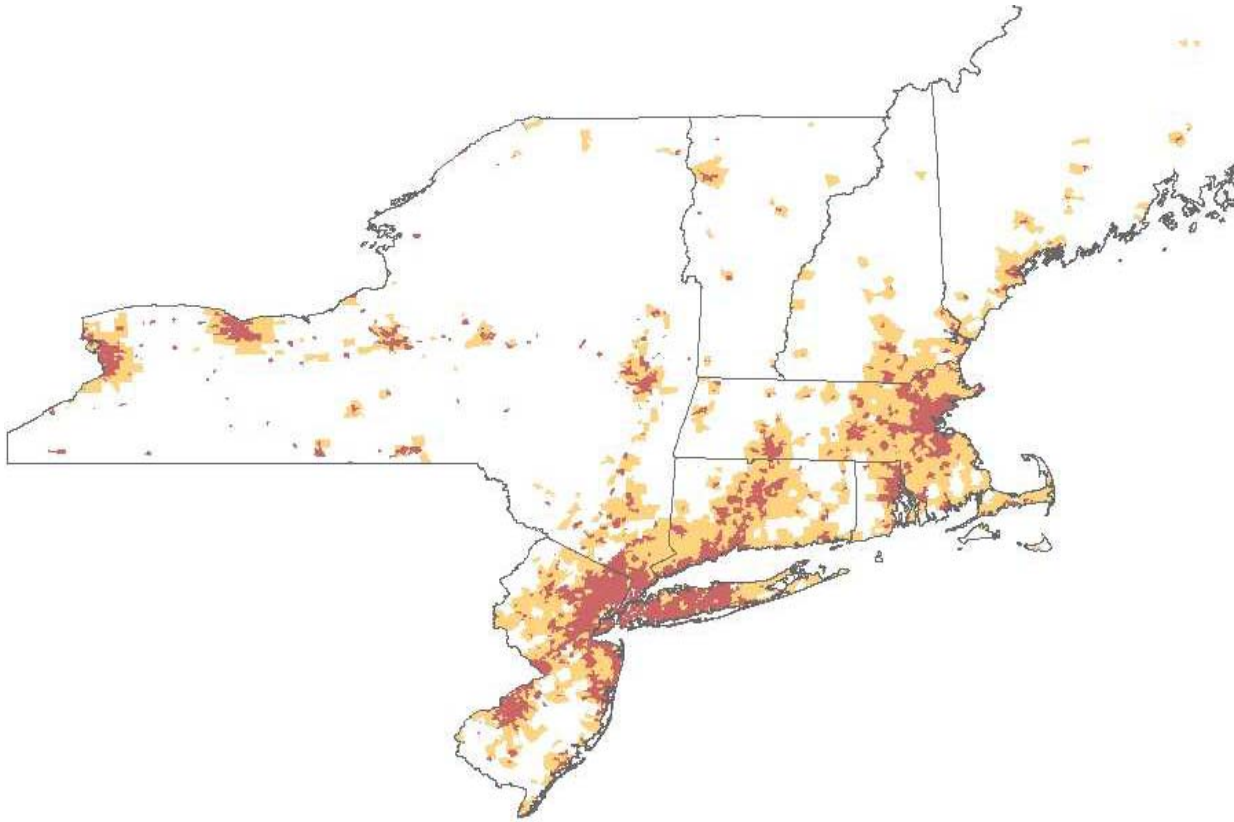
Table 4: Current PM$_{2.5}$ primary standards/guidelines of selected organizations

Organization	Annual mean (µg/m^3)	24-hour average (µg/m^3) (98th percentile form)
U.S. EPA Standards[1], 1997	15	65
EPA Recommendation: 2003 1st draft SP[2]	12-15	30-50
EPA Recommendation: 2004 2nd draft SP	Expected January 31, 2005	
State of California Standards[3], 2003	12 (not to be exceeded)	n/a[4]
Canada-Wide Standards[5], 2000	n/a	30
NESCAUM, 2004	12	30

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[1] 40 CFR Part 50, National Ambient Air Quality Standards for Particulate Matter, Final Rule. Federal Register / Vol. 62, No. 138 / Friday, July 18, 1997.

[2] Available at: http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html

[3] The new standards amount to new clean air goals for the state and took effect in June 2003. California Environmental Protection Agency, Air Resources Board. Staff Report: Public Hearing to Consider Amendment to the Ambient Air Quality Standards for Particulate Matter and Sulfates. May 2002. El Monte, CA. Available at: http://www.arb.ca.gov/research/aaqs/std-rs/pm-final/pm-final.htm

[4] In May 2002, California Air Resources Bureau (CARB) staff recommended a new 24-hour average standard for PM$_{2.5}$ at 25 µg/m^3, not to be exceeded, but subsequently deferred a final decision until after the reanalysis of time-series studies using S-Plus statistical software. California retained both its 24-hour average standard of 50 µg/m^3 for PM$_{10}$ not to be exceeded and its 24-hour average standard for sulfates at 25 µg/m^3. Available at: http://www.arb.ca.gov/research/aaqs/std-rs/2_5defer.htm

[5] Target implementation to be achieved by 2010 and ratified by ministers on June 2000. CWS represents a balance of two considerations: 1) best possible protection of human and environmental health in near term; 2) feasibility and cost of reducing pollutant emissions that contribute to elevated levels of PM in air . Canadian Council of Ministers of the Environment. Canada-wide standards for particulate matter (PM) and ozone. 2000. Available at: http://www.ccme.ca/initiatives/standards.html?category_id=59#34

NESCAUM staff analysis of primary PM$_{2.5}$ standards

1. Relationship between annual and daily PM$_{2.5}$ levels

Figure 2 plots the site by site relationship between the annual mean and the 24-hour average (98th percentile form) for Regions 1, 2 and border states, allowing one to track how changes in either metric influence stringency across monitors. A considerable scatter of values occurs across the average of all three years (2000-2002). For example, a site with an annual mean of 12 µg/m^3 can experience a 24-hour average ranging from 30-34 µg/m^3. Likewise, a site with a 24-hour average of 30 µg/m^3 experiences an annual mean ranging from over 9-13 µg/m^3.

Figure 3 demonstrates this relationship for broad areas across the United States.[6]

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[6] For Figure 1, NESCAUM performed calculations from individual data points. For Figure 2, NESCAUM used EPA calculations. All data were obtained from: http://www.epa.gov/air/data/index.html

NESCAUM staff interpretation of findings

➢ Considerable variability exists in 24-hour average values for sites with similar annual means, as well as variability in annual mean values for sites with similar 24-hour average values. As a result, annual standards may actually fail to constrain 24-hour fine particle levels; conversely, 24-hour standards may fail to constrain annual levels.

➢ A suitable combination of appropriately stringent annual and 24-hour standards might have optimum controlling effect throughout the entire distribution of $PM_{2.5}$ values.

Figure 2: Relationship between annual mean and 24-hour average PM$_{2.5}$ standards (3-year average) (FRM 8 NESCAUM states, DC, DE, MD, PA: 2000-2002).
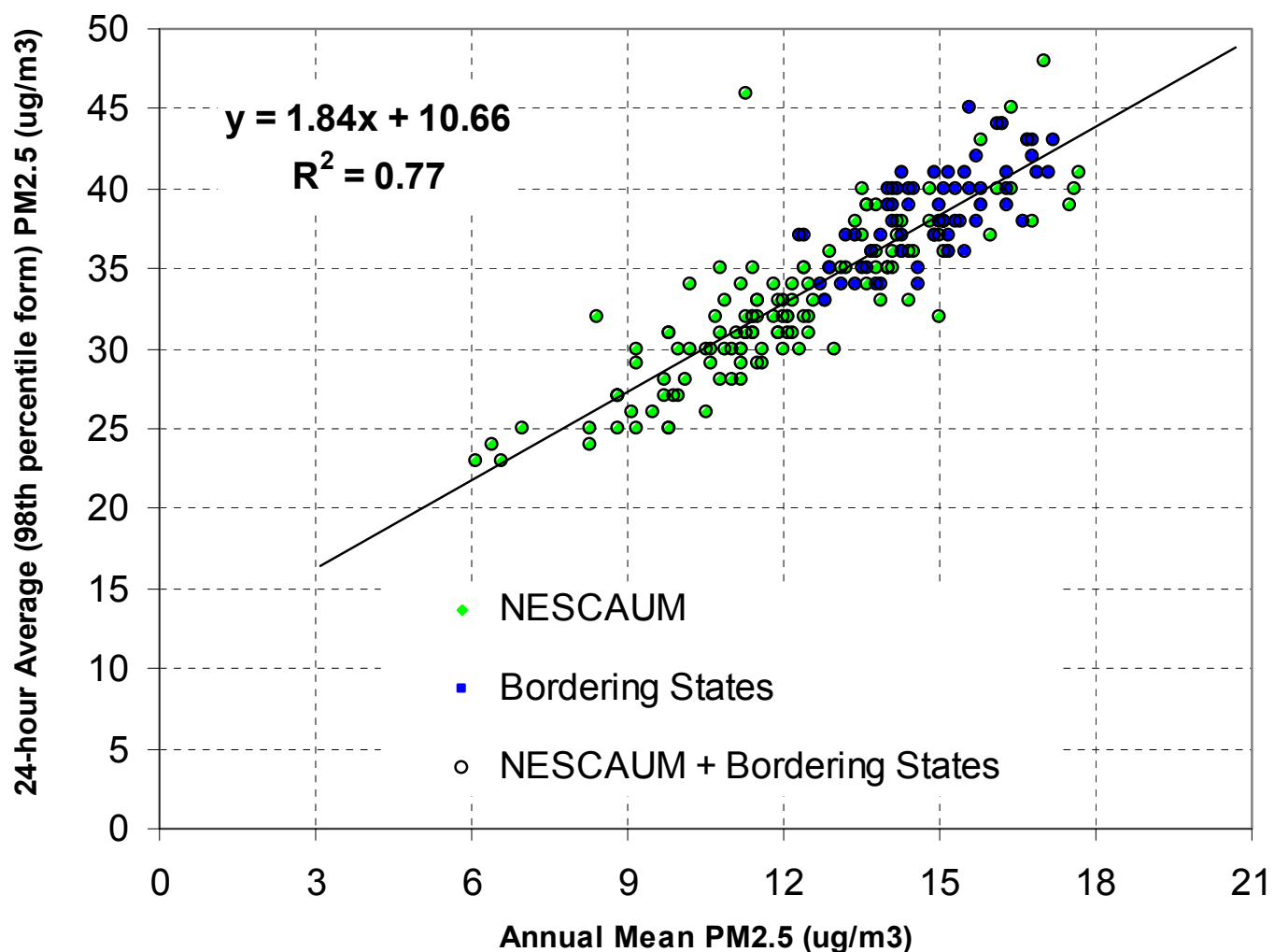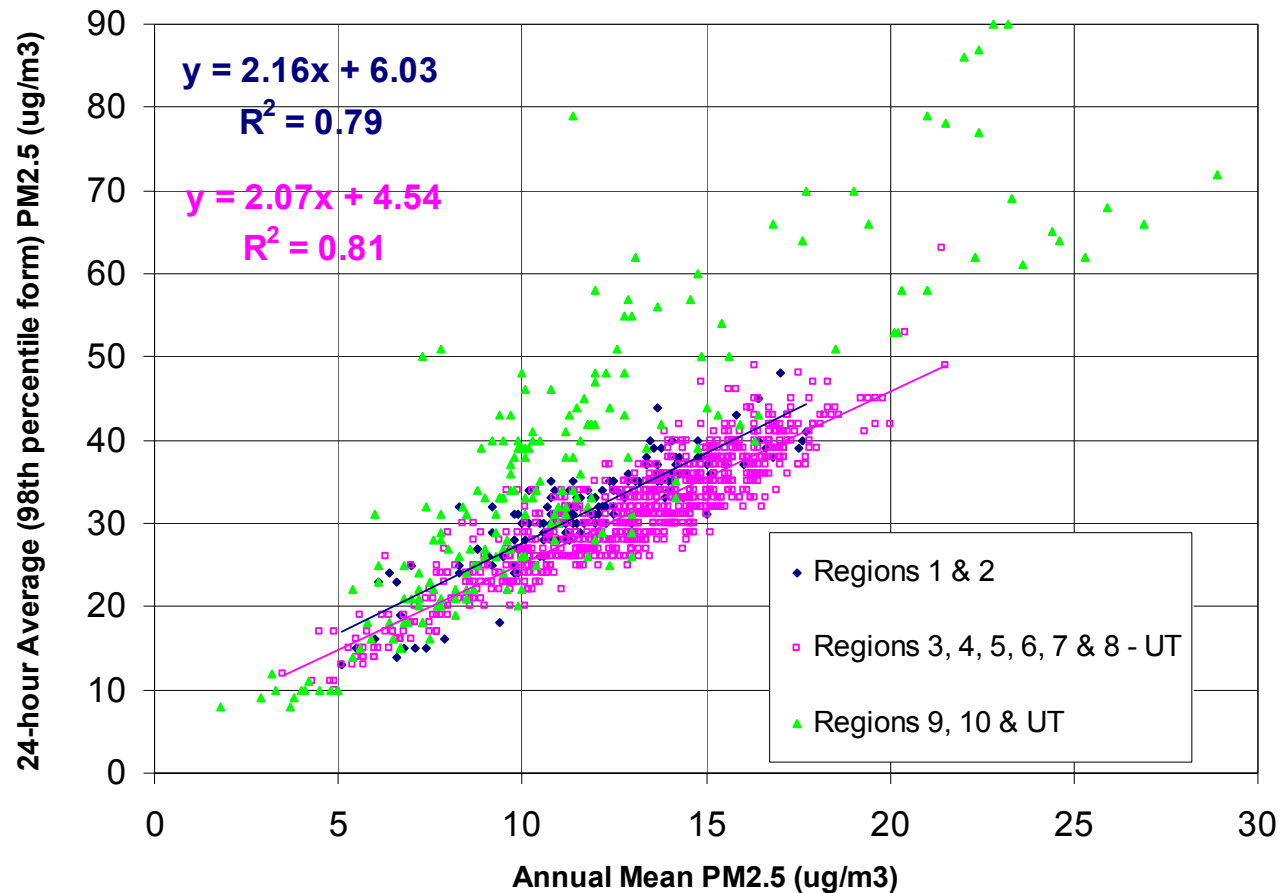
Figure 3: **Relationship between annual mean and 24-hour average PM$_{2.5}$ standards (3-year average) (FRM EPA Regions 1-10: 2000-2002).**

2. Effect of alternative PM$_{2.5}$ standards on populations

Figure 4 shows the counties/population age groups[7] that would benefit from compliance with PM$_{2.5}$ levels less or greater than various combinations of annual and 24-hour average (98th percentile form) concentrations. The analysis is based on 150 counties in Regions 1 and 2, where the highest annual or daily interpolated values were used to assign PM$_{2.5}$ levels to the 80 counties without monitoring values for the three-year period.[8] Monitoring data were used from within and immediately outside the NESCAUM region.

Figures 5 and 6 show adult and children populations with chronic cardiopulmonary conditions and diabetes[9] that would benefit from compliance with PM$_{2.5}$ levels less or greater than various combinations of annual and 24-hour average (98th percentile form) concentrations. The analysis uniformly applies Centers for Disease Control and Prevention (CDC) prevalence rates for selected health conditions to the number of persons living in areas with PM$_{2.5}$ concentrations above each annual/daily standard combination.

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[7] Persons aged 0-17 and 65+ represent susceptible subpopulations potentially at increased risk for ambient PM-related morbidity or mortality effects. These selected data do not encompass all potential categories of susceptibility and persons may be represented in multiple categories.

[8] The methods of determining design values are analogous to Table 6-1 in EPA's *1st Draft PM Staff Paper*. In Table 6-1, EPA assessed the percentage of counties that would not likely achieve combinations of annual and 24-hour PM$_{2.5}$ alternative standards. EPA's analysis, however, is not specific to the NESCAUM region and does not provide information on population numbers. Nor does Table 6-1 estimate PM levels in non-monitored counties. EPA PM Staff Paper available at: http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html

[9] Persons with heart disease, lung disease, or diabetes represent susceptible subpopulations potentially at increased risk for ambient PM-related morbidity or mortality effects.

NESCAUM staff interpretation of findings

➢ Depending on the combination of $PM_{2.5}$ standards chosen by EPA, NESCAUM region counties with a substantial fraction of the region's total population may be below or above alternative levels.

➢ A significant percentage of the NESCAUM region population is potentially susceptible to $PM_{2.5}$ based on age group and on preexisting health condition. The public health implication of PM NAAQS could be substantial.

➢ While attainment of NAAQS does not imply total elimination of health risks, incrementally more stringent standards would provide more public health protection.

Figure 4: Percent of NESCAUM population that would benefit from compliance with alternative annual/daily $PM_{2.5}$ standards.
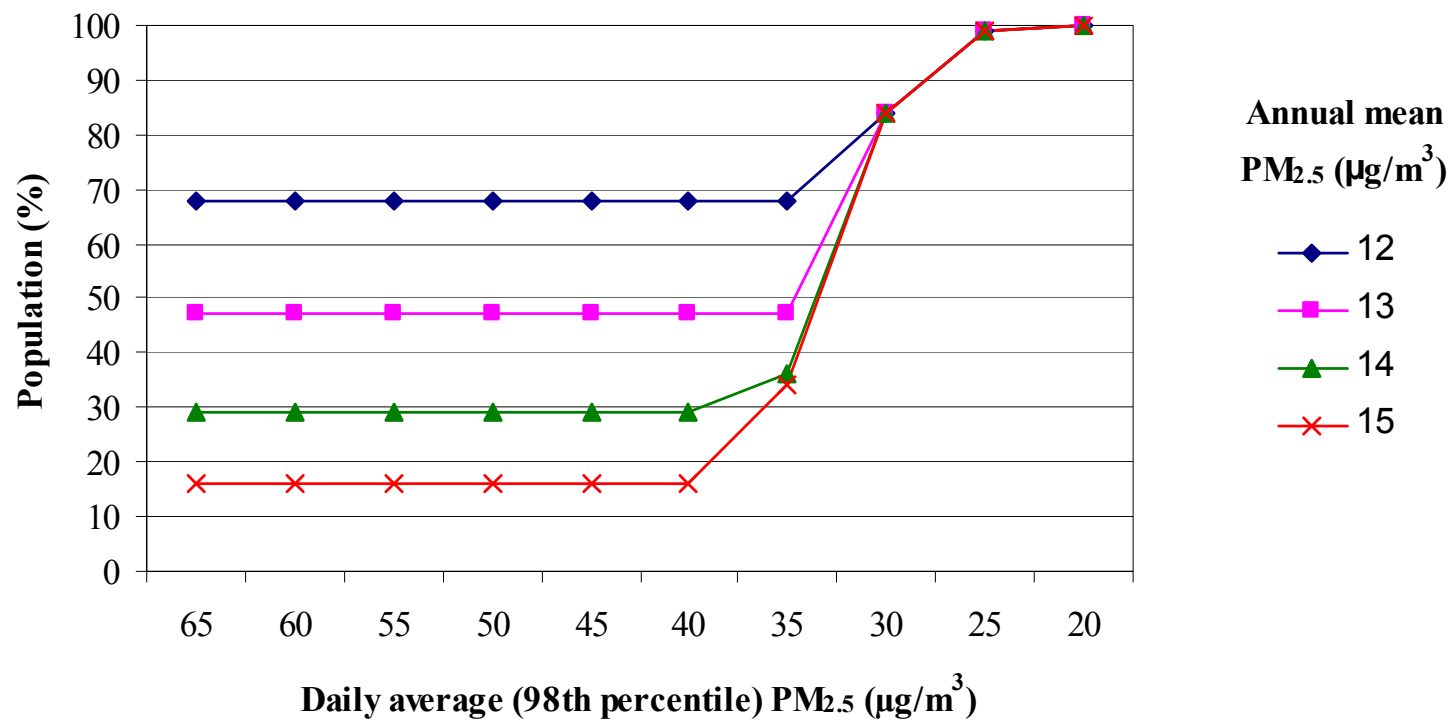
Figure 5: Percent of NESCAUM adults with selected disease conditions that would benefit from compliance with alternative annual/daily PM$_{2.5}$ standards.
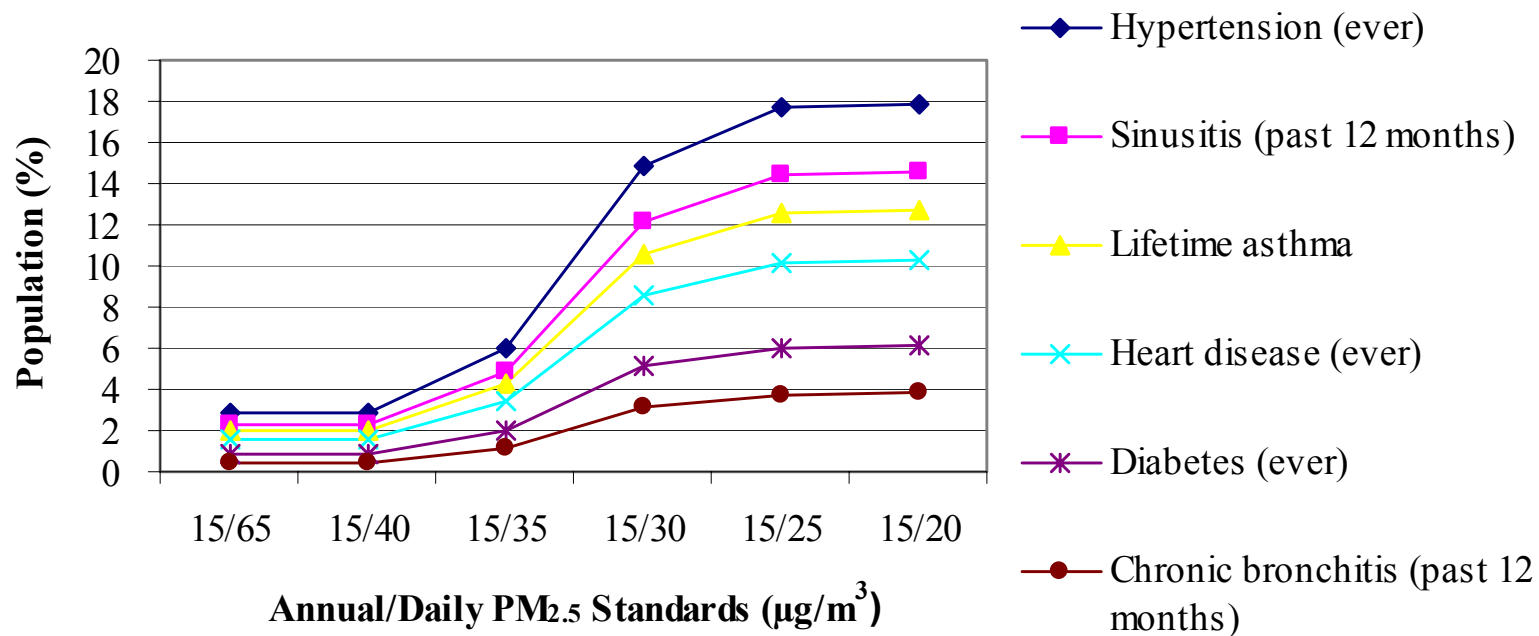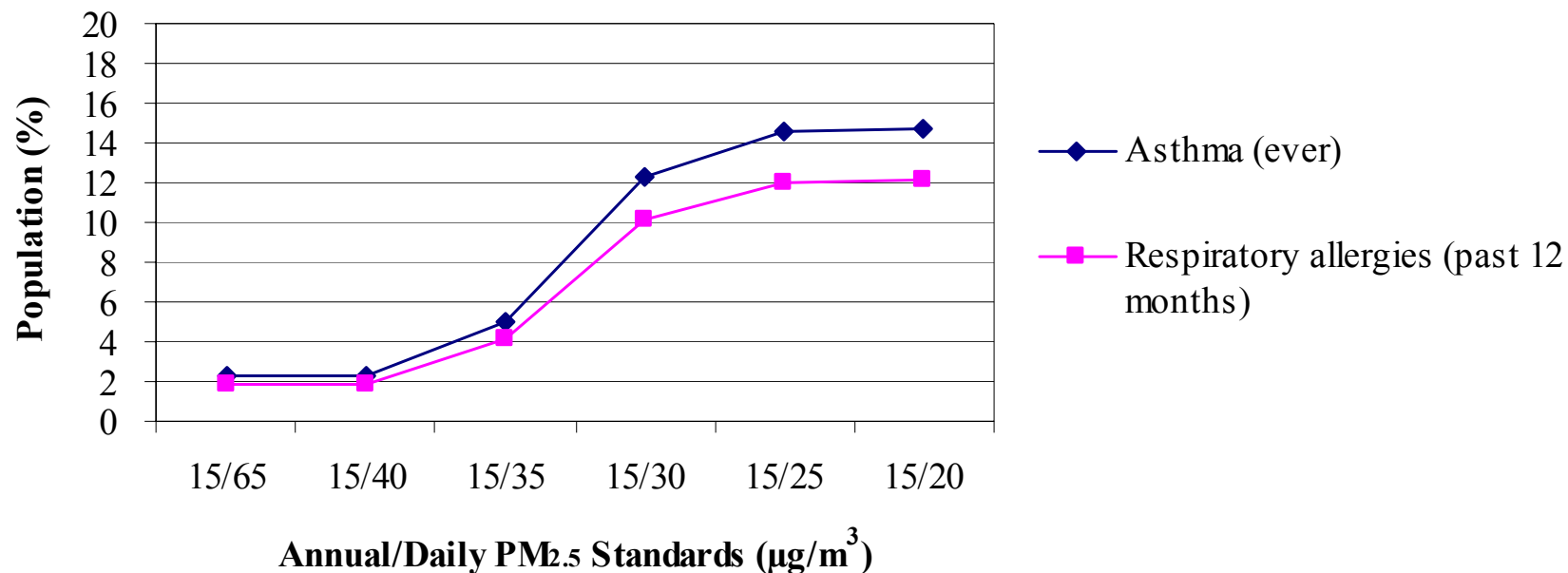
Figure 6: **Percent of NESCAUM children with selected disease conditions that would benefit from compliance with alternative annual/daily PM$_{2.5}$ standards.**

Summary

➢ In the NESCAUM region (and much of the U.S.) considerable variability exists in 24-hour average values for sites with similar annual means, as well as variability in annual mean values for sites with similar 24-hour average values. As a result, annual standards may actually fail to constrain 24-hour fine particle levels; conversely, 24-hour standards may fail to constrain annual levels.

➢ A suitable combination of appropriately stringent annual and 24-hour standards might have optimum controlling effect throughout the entire distribution of $PM_{2.5}$ values.

➢ Depending on the combination of $PM_{2.5}$ standards chosen by EPA, NESCAUM region counties with a substantial fraction of the region's total population may be below or above alternative levels.

➢ A significant percentage of the NESCAUM region population is potentially susceptible to $PM_{2.5}$ based on age group and on preexisting health condition. The public health implication of PM NAAQS could be substantial.